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A Research on the Evaluation of the Operating Efficiency and Innovation Efficiency of China's Development Zones Based on Panel Data

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Abstract

Development zones have been playing an increasingly important role over the 30 years of development in national economy so it is of great significance to evaluate the operating efficiency and innovation efficiency of development zones. Based on the panel data from 2008 to 2014, the author has evaluated the dynamic efficiency of 27 provincial capitals' development zones adopting DEA approach. The research has found that the operating efficiency of China's development zones remains on an ideal level but there is development imbalance among different regions; the development zones have higher innovation efficiency while R&D activities are in need of further improvement; development zones face greater urgency to improve their operating efficiency; in the end, the article has proposed some relative policy suggestions.

Key words: Development zones; Operating efficiency; Innovation efficiency

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INTRODUCTION

Since the Torch Plan was implemented over 20 years ago, all high-tech zones and development zones have made fast progress and facilitated China's technological progress, investment promotion, industrial conglomeration, and urban growth. However, most of development zones in China have focused on the manufacturing industry and stayed in the lower part of value chain, ignoring the cultivation of innovation ability (Zhang, 2015). With the pressure on industrial transformation and upgrading growing, the domestic development zone's shortcoming in R&D has been exposed, which is going to limit the potential of development zone's growth.

The priority of developing development zones is to facilitate economic growth and play a leading and promoting role (Anastasia, 2012; Xu, 2007) applied DEA model to analyzing the efficiency of 53 national high-tech zones and found the comprehensive efficiency is higher in the zones in eastern part of China than their counterparts in the western part. Yang et al. (2013) applied SBM-VRS model to evaluate the economic efficiency of China's national high-tech zones and found that the trade opening level has remarkably drove the growth of empirical efficiency in high-tech zones. Wu and Li (2013) applied output DEA and found the mean value of technological efficiency of add-on 56 national high-tech zones was 0.45, which is not ideal. Gu (2014) applied factor analysis and clustering method to evaluate development zone's economic competitiveness, pointing out the imbalance in China's development zones. Meanwhile, China's development zone has the responsibility to develop and industrialize high technologies and the important role in regional innovation. To study it, Yang et al. (2009) has visited Taiwan Hsinchu Science and Technology Park and found the in-zone enterprises have a higher output elasticity and investment efficiency than others, which prove the existence of R&D conglomeration effects. Wu and Yu (2010) pointed out that research input is an important factor affecting development zones' innovation efficiency. Jiang (2012) pointed out, after visiting TFP, that during the development process, the development zones will first be driven by the growth effect and then

catch-up effect. Yang et al. (2013) also pointed out that opening-oriented policy will have negative effects on development zone's research efficiency.

To sum up, for a long time domestic and foreign scholars have paid attention to the development on the levels of country, region, industry and enterprise, including economic growth efficiency, innovation efficiency, development path, etc.. Few have focused on the efficiency evaluation on the development zone level; on the other hand, aside from the high-tech zones' innovation efficiency, the current efficiency evaluation studies of development zones have focused on economic and technological levels, while few have put them into an analysis frame. Therefore, this article has studied 27 national development zones and divided development zone's efficiency into operating efficiency and innovation efficiency. Operating efficiency refers to the development zone's resource allocation ability, organization level and conglomeration effect, while innovation efficiency refers to the development trend and direction. After studying the dynamic variation of operating efficiency and innovation efficiency from 2008 to 2014, the article has come to some revelatory conclusions.

1. RESEARCH SAMPLE AND MODEL SETTING

1.1 Method

Currently there are 2 kinds of methods to evaluate efficiency: One is parametric method, represented by Data Envelopment Analysis proposed by Charness, Cooper, and Rhodes (1978); the other one is non-parametric method, represented by Stochastic Frontier Approach proposed by Aigner, Lovell, and Schmidt (1977). The former method adopts mathematical programming approach, which has advantages in evaluating the efficiency of big input and output. But since the DEA has restricted boundary conditions and has no consideration of measurement errors, this method has the obvious disadvantage. SFA adopts metering methods to evaluate the frontier production function. This method relies on the random hypothesis of data, and therefore, has stronger economic theory foundation. However, it has limits in function form setting and high requirement for distributional hypothesis. So it can only be used in limited areas. In a word, two methods should be adopted according to specific situations.

Based on the previous studies, academic circles often adopted DEA to analyze efficiency measurement (Xu, 2007; Jiang & Xu, 2009; Zheng, 2012). DEA method estimates the stochastic frontier of the valid production based on a group of observed values, and then finds the relative efficiencies of different decision units (DMU). Based on the panel data of China's 27 provincial and municipal development zones, the article has applied DEA in analyzing operating efficiency and innovation efficiency.

1.2 Parameter Determination

To evaluate development zone efficiencies by DEA requires selecting input-output index at first. According to development zone operating efficiency, Kebu-Douglas function is often adopted to measure the inputs in the aspects of labor, capital and resources. Output index usually includes total industrial output value and net profit (Cai & Lu, 2014). Based on the previous studies and considering the accessibility of data, this article has selected the following factors as input-output index of development zone operating efficiency: number of enterprises, capital input, number of personnel with medium and advanced occupational titles, net profit, and total industrial output value.

In the researches on innovation efficiency, researchers usually conduct measurement by adopting the factors of R&D expense, number of R&D personnel, and full-time equivalent. Some other researchers believe R&D capital stock is a better input indicator; there are many innovation output indexes. First of all, patent has been widely used as an index to measure innovation efficiency. But patent output is still intermediate product of R&D input and more suitable to measure innovation efficiency of colleges and research institutions, though it can't completely represent enterprises' R&D output; Secondly, some scholars believe new products' sales revenue is a more visual output index (Yang, 2013; Zuo, 2015), which can reflect the commercialization of enterprise R&D and the R&D input value in technological process and quality improvement; However, new product revenue alone will be insufficient because the growth in the revenue is unnecessarily the result of R&D input during the same period. Besides, this index hasn't considered technological transfer income, technical contract and technical service income that occurred during the enterprises' R&D process. Therefore, in this article technical income has been selected as the output index, while the number of technical activity participants, internal technical activities expenditure, and internal R&D expenditure as the input index for development zone innovation efficiency measurement.

College internal R&D expenditure includes research labor cost and fixed assets based on non-capital construction investment. The evaluation of the expenditure is influenced by the rate of capital depreciation, price index of investment in fixed assets. This article has been referred to the approach adopted by Zhou and Deng (2009). and given consideration to the similar trends of labor cost and equipment fees in the internal scientific and technological expenditures over years. And therefore, the R&D price index is set as follows:

$$PR = (P + W) / 2 .$$

P stands for the price index of investment in fixed assets over years, W stands for consumer price index

(CPI) over years. As for the R&D capital depreciation rate, many empirical studies chose a fixed constant as the rate. However, considering the disparities in different regions of China, this article has referred to Wang's (2011) approaches and adopting different R&D capital depreciation rates for different regions. Specifically, the rates for the eastern, central and western regions are respectively 18%, 15%, and 12%. Therefore, this article has chosen 2008 as the benchmark year, and the annual R&D capital stock is as follows:

$$RD_{it} = (1 - \delta)\, RD_{i(t-1)} + E_{it}.$$

RD_{it} stands for the R&D capital stock in region i during year t, δ stands for R&D capital depreciation rate, E_{it} stands for the added R&D expenditure deflated by price index (PR) in region i during year t.

1.3 Data Source and Descriptive Statistics

Considering the accessibility and consecutiveness of data, this article has chosen 27 provincial capitals' development zones to study and acquired the data from China Torch Statistical Yearbook and the statistical yearbooks of each province and city over the years. To study these development zones are based on the following consideration: (a) long history and close establishment time; (b) relatively compete data; (c) development zones in provincial capitals enjoy educational and geographical advantages, which are in the favor of enterprises' R&D activities, and can get incentives. In 2014, the R&D expenditure of the 27 development zones in provincial capitals accounted for over 80% of the R&D expenditure of all development zones.

Time horizon is set between 2008 and 2014, after considering the consistency and integrity of data on the one hand, and on the other hand, China's strategy of "building a country of innovation" being carried out in 2006. Descriptive statistics of major parameters are as follows:

Table 1
Descriptive Statistics (unit: 1,000 yuan)

		N	Mean	*SD*	Min	Max
Output index	Technical income	189	2.67×10^7	5.24×10^7	167261	4.03×10^8
	Net profit	189	1.68×10^7	2.46×10^7	227044	1.91×10^8
	Total industrial output value	189	1.73×10^7	1.37×10^7	7486271	7.89×10^8
Input index	Capital input	189	2.41×10^8	3.41×10^8	1.14×10^7	2.86×10^9
	Personnel with medium and advanced occupational titles	189	31358	44441	1937	304936
	Number of technical activity participants	189	44030	63836	1559	411088
	Internal technical activities expenditure	189	8844002	1.38×10^7	88015	1.03×10^8
	Internal R&D expenditure	189	4963293	6849311	5176	4.56×10^7
	Enterprise number	189	1495	3093	108	18611

Particularly, the DEA model's monotony requires that the growth of any input variant will not reduce any output variant; otherwise the variants concerned must be converted before put into DEA model to be analyzed. This article has adopted relative coefficients to check the monotony of variants, and the result shown that all the input variants and output variants have positive correlation, which has met the requirement of monotony and therefore can be put into the DEA model to be analyzed.

2. INTERPRETATION OF REGRESSION RESULTS

2.1 Operating Efficiency of Development Zones

By adopting DEAP2.1 software to calculate Malmquist indexes of the data from 2008 to 2014, the results are shown in Tables 2 and 3.

As shown in Table 2, the change rate of technical change (TC) from 2008 to 2014 is below 1, the rates in other years are above 1. These show the fast technical progress of the development zones in 27 provincial capitals over 7 years. But according to TEC, the relative technical efficiency progress is unsteady, featuring interval trends. Pure technical efficiency (PTEC) shows the same feature. However, except for 2011, all the scale efficiency (SEC) of development zones in 27 provincial capitals is below 1, which shows the imbalance of economic growth. In the end, except for 2009, the total factor productivities of 27 development zones are all over 1.

Generally speaking, from the analysis above, the progress of technical efficiency of the development zones in 27 provincial capitals from 2008 to 2014 are mainly because of the growth in technical change index and

pure technical efficiency, which shows that innovation in production technologies and technological progress has facilitated the growth in development zones' operating efficiency.

Table 2
2008-2014 TPF Indexes of Development Zones' Operating Efficiency in Each Year

Year	TEC	TC	PTEC	SEC	TFPC
2008-2009	1.000	0.986	1.006	0.994	0.986
2009-2010	0.912	1.149	0.950	0.960	1.048
2010-2011	1.028	1.038	1.017	1.01	1.066
2011-2012	0.988	1.038	0.994	0.993	1.025
2012-2013	0.977	1.025	1.002	0.975	1.002
2013-2014	1.034	0.973	1.041	0.994	1.006
Mean	0.989	1.033	1.001	0.988	1.022

As shown in Table 3, from 2008 to 2014, there are 19 provincial capitals' development zones whose TFPC indexes growth rates were over 1. The TFPC of Changchun was as high as 1.149. Since the growth in Malmquist index is derived from the changes in technical change efficiency (TC), therefore the development zones' greater input in technical factors has got obvious results.

To further evaluate the comprehensive operating efficiency of development zones, the article has chosen the cross-section data of 2014 to survey, substituted the input and output data of operating into BCC model, solved the model and got the comprehensive efficiency, pure technical efficiency and scale efficiency, and the redundancy and deficiency of each indexes. Since there are many samples, the article has conducted the statistics of mean operating efficiency based on regions.

As shown in Table 4, the mean comprehensive efficiency of 27 provincial capitals' development zones is 0.845, which is on an ideal level, pure technical efficiency 0.932, scale efficiency 0.908. These show the relative balance among the development of these development zones. In terms of regions, the eastern and western regions' comprehensive efficiencies are lower than the national mean value, mainly because the East has lower pure technical efficiency and the West has lower scale efficiency. From the point of return to scale, the returns to scale in most of the development zones in the provincial capitals in the eastern and central regions have started to decrease progressively, while the returns to scale in their western counterparts increase progressively. This is mainly because that the economic development in the East and the Central started earlier, the business competition is fierce, and the labor costs are higher. All these factors have brought down comprehensive operating efficiency.

Table 3
2008-2014 TPF Indexes of Development Zones' Operating Efficiency in Each City

City	TC	PTEC	SEC	TFPC	City	TC	PTEC	SEC	TFPC
Beijing	1.043	1	0.964	1.006	Jinan	1.103	0.99	0.991	1.081
Tianjin	1.055	1	1	1.055	Zhengzhou	1.01	0.989	0.999	0.998
Shijiazhuang	1.003	0.994	0.98	0.977	Wuhan	1.005	0.997	0.973	0.975
Taiyuan	1.002	0.987	0.993	0.982	Changsha	1.008	1.014	0.996	1.018
Shenyang	1.005	0.988	1.002	0.995	Guangzhou	1.002	1.003	1	1.005
Changchun	1.149	1	1	1.149	Nanning	1.013	1.013	0.995	1.021
Harbin	1.02	0.975	0.995	0.989	Chongqing	1.043	1.042	0.984	1.07
Shanghai	1.131	1	0.962	1.088	Chengdu	1.001	0.999	0.988	0.988
Nanjing	1.08	1	1	1.08	Guiyang	1.039	1	1.001	1.04
Suzhou	1.028	0.991	0.997	1.016	Kunming	1.048	1	0.955	1.001
Hangzhou	1.027	1.039	0.998	1.065	Xi'an	1.007	1.035	0.978	1.02
Hefei	1.044	1	1	1.044	Lanzhou	0.973	0.984	0.935	0.896
Fuzhou	1.011	1	1	1.011	Urumuqi	1.053	1	0.984	1.037
Nanchang	1.008	0.997	1	1.005					

2.2 Innovation Efficiency

As shown in Table 5, after studying 27 provincial capital development zones, the mean value of 5 indexes is above 1, which shows each one's efficiency has a growing trend. Change rates of the technical change indexes are below 1 only in 2012 and 2013, and above 1 in all the other years. From the aspect of TEC, the relative technical efficiencies of these development zones from 2009 to 2011 are below

1, and above 1 after 2011, while in some years, this figure can reach 1.829; pure technical efficiency shows an opposite trend compared with technical change index; secondly, scale efficiencies in 2010, 2011, and 2014 are all below 1, which shows that these development zones' innovation efficiencies haven't reached balance; in the end, except for 2010, 27 development zones' total factor productivity are all above 1.

In general, from 2008 to 2014, 27 provincial capital development zones' innovation efficiencies have an opposite trend compared with their operating efficiencies. In later period, pure technical efficiency and scale efficiency together facilitated the growth of comprehensive efficiency, while in the earlier period (2009-2011), technical progress has brought total factor productivity above 1.

Table 4
DEA Average Efficiency and Returns to Scale of Development Zones in Different Regions

Region	Number of dev. zones	Compre-hensive efficiency	Pure technical efficiency	Scale efficiency	Returns to scale (number of dev. zones)		
					increase	decrease	invariant
Whole	27	0.845	0.932	0.908	11	11	5
East	11	0.843	0.915	0.925	3	5	3
Center	8	0.882	0.916	0.963	2	4	2
West	8	0.809	0.972	0.831	6	2	0

Table 5
2008-2014 TPF Indexes of Development Zones' Innovation Efficiency in Each Year

Year	TEC	TC	PTEC	SEC	TFPC
2008-2009	0.996	1.065	0.984	1.012	1.06
2009-2010	0.915	1.086	0.987	0.927	0.994
2010-2011	0.762	1.49	0.904	0.842	1.135
2011-2012	1.829	0.702	1.356	1.349	1.284
2012-2013	1.209	0.966	1.122	1.078	1.168
2013-2014	1.096	1.066	1.228	0.893	1.168
Mean	1.091	1.037	1.086	1.004	1.131

As shown in Table 6, 21 provincial capital development zones' TFP indexes all had growth rates above 1, among which, Harbin's TFPC was as high as 1.667. Since the growth of Malmquist indexes is mainly derived from changes in technical change efficiency (TC), therefore the increased input in technical factors has a remarkable effect.

By comparing with Table 3 and Table 6, the TFPC of the 19 development zones' innovation efficiencies is bigger than the TFPC of their operating efficiencies (among which, 6 development zones' innovation efficiencies have a TFPC that is above 1, while their operating efficiencies have a TFPC that is below 1). This shows, in general, the 27 provincial capital development zones' innovation efficiencies have a better performance than their operating efficiencies.

Table 6
2008-2014 TPF Indexes of Development Zones' Innovation Efficiency in Each City

City	TC	PTEC	SEC	TFPC	City	TC	PTEC	SEC	TFPC
Beijing	1.042	1.000	1.083	1.129	Jinan	1.059	1.432	0.979	1.484
Tianjin	1.056	1.052	1.026	1.141	Zhengzhou	1.000	1.038	1.004	1.042
Shijiazhuang	1.028	1.497	1.014	1.562	Wuhan	1.024	1.170	0.993	1.190
Taiyuan	1.054	0.992	1.014	1.061	Changsha	0.987	1.170	0.993	1.147
Shenyang	1.054	0.962	0.977	0.991	Guangzhou	1.071	1.052	0.960	1.082
Changchun	1.036	1.438	1.011	1.507	Nanning	1.068	0.896	0.996	0.953
Harbin	1.056	1.584	0.997	1.667	Chongqing	1.015	1.046	1.013	1.076
Shanghai	1.056	0.927	1.026	1.005	Chengdu	1.049	1.102	1.065	1.231
Nanjing	1.070	0.954	1.003	1.025	Guiyang	1.112	0.848	0.999	0.942
Suzhou	1.074	1.003	0.972	1.046	Kunming	1.034	1.307	1.015	1.372
Hangzhou	1.031	0.997	0.965	0.992	Xi'an	1.014	0.957	0.993	0.963
Hefei	1.060	1.149	0.956	1.165	Lanzhou	0.893	1.000	1.000	0.893
Fuzhou	1.033	1.069	1.000	1.105	Urumuqi	1.002	1.000	1.073	1.075
Nanchang	1.047	1.063	0.997	1.110					

CONCLUSION

This article has adopted DEA model to measure and evaluate the operating efficiency and innovation efficiency of 27 provincial capital development zones and found the principal factors that restrict development zones from lifting their total factor productivity. The conclusions are as follows:

(a) From the general efficiency evaluation, 27 provincial capital development zones' operating efficiency maintains on a reasonable level with remarkable disparities in operating efficiency in different regions. Eastern and western regions have lower comprehensive efficiency, but development zones in the western region have remarkably better returns to scale than their eastern and central counterparts.

(b) From 2008 to 2014, 27 provincial capital development zones have relatively good innovation efficiency, among which 21 development zones have TFPC that is above 1, which shows that all the development zones have responded to the national "innovation-driven growth strategy" and "strategy of building a country of innovation" by making great efforts in facilitating technical progress. However, R&D activity management ability which represents technical change efficiency is still weak and requires further enhancement.

(c) By comparing operating efficiency and innovation efficiency, the article has found that 27 development zones' innovation efficiency has a better performance.

SUGGESTION

According to conclusions above, in order to boost the operating efficiency and innovation efficiency of development zones, this article has proposed the following policy suggestions from the aspects of government, industry and enterprise:

(a) All levels of governments should pay more attention to regulation, control and guidance, optimize development zone's structure, in order to solve the imbalance between input and output and improve development zone's operating efficiency and innovation efficiency. Meanwhile, each province and city should make niche-targeting policies based on their own conditions. To specify, governments in the eastern and central regions should give more attention to market environment and cultivate good business environment, while governments in the western region should encourage enterprises to grow and strengthen and enlarge their development zones.

(b) Aside from continued promoting technical level, China's in-zone enterprises should pay more attention to R&D management ability enhancement. For the development zones in the eastern region which has lower operating efficiency, they should continue promoting in-zone enterprises production, operating and management abilities, optimizing the usage of R&D capital; those in the central region should pay more attention to labor cost control; those in the western region should continue bringing in advanced technologies and equipments, promoting their technical level.

(c) For most of the domestic development zones, the most urgent task is still to promote operating efficiency, and then innovation efficiency.

The deficiency of this study is in the following aspects. For lack of data and other reasons, only the number of technical active participants is used to measure the development zone's human capital input. This variant can't fully represent most of the development zones whose major industry is manufacturing and has influence over the final evaluation. Secondly, the conclusion has certain amount of inadequacy considering the fact that only 27 provincial capital development zones have been chosen out of the 219 national development zones in China. More specific studies can be conducted with sole focus on either operating efficiency or innovation efficiency.

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